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ABSTRACT

The purpose of this experiment was to analyze developmental differences in rehearsal strategies which may mediate the commonly found age effect on free recall. As expected, significant age differences in recall were found; analysis of rehearsal strategies showed that fifth and eighth graders tended to repeat stimulus words immediately after presentation and not to enter items into subsequent rehearsal sets. Adults, in contrast, tended to re-enter items for additional rehearsal and had larger rehearsal buffers. Immediate repetition may have served as additional massed presentation trials, which are less consequential for learning than later re-entry of items (spaced trials). It was inferred that children engaged primarily in maintenance rehearsal, and adults in both maintenance and elaborative rehearsal. (Author)

DEVELOPMENTAL DIFFERENCES IN REHEARSAL AND FREE RECALL[1]

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A number of different models have been proposed to explicate the nature of storage and retrieval processes in memory (e.g., Atkinson & Shiffrin, 1968; Bower, 1967; Waugh & Norman, 1965). The supporting data for these models has been contributed primarily by college adults; however, there is a paucity of research investigating the development of these memory processes from childhood to adulthood (e.g., Goulet, 1968; Keppel, 1964).

In the child verbal learning literature, one of the most consistent findings has been an increase in word recall as a function of age (e.g., Cole, Frankel, Sharp, 1971). It has been suggested that adults and older children, in contrast to younger ones, use more active and effective rehearsal mechanisms to improve recall, especially for early and middle list items (e.g., Cole, et al., 1971; Flavell, Beach, & Chinsky, 1966). Speculation about storage processes in children's memory generally has been based on very indirect measures such as children's lip movements and pointing (e.g., Flavell, et al., 1966), the degree of primacy and recency effects evidenced on serial position curves (e.g., Hagen & Kail, 1973), and organization of recall (e.g., Bousfield, Esterson, Whitmarsh, 1958). Although the quality and quantity of rehearsal in memory has been the subject of conjecture, there is a dearth of experimental data describing specific rehearsal strategies and how they change as a function of age.

Recently, Rundus (1970; Rundus & Atkinson, 1970) employed an overt rehearsal procedure with adults in order to examine more directly the

rehearsal-recall relationship. Rehearsal was operationally defined as stimulus repetition. A positive correlation between overt rehearsal and free recall was found, as well as several rehearsal strategies which adults employed during memory storage. Subjects' overt rehearsal was tape recorded and analyzed for such variables as: number of repetitions per list accorded a stimulus word; number of different items rehearsed per rehearsal set; number of repetitions granted a word in the rehearsal set immediately following its presentation; and, number of different rehearsal sets in which a stimulus item appeared.

Fagan (1972) required children matched on chronological age but varying on I.Q. to rehearse aloud a list of common words presented for single-trial free recall. Children of superior intelligence produced greater rehearsal and recall. These differences obtained only for the initial and middle segments of the serial position curve, but not the terminal positions.

Cuvo (in press) employed the overt rehearsal procedure to examine incentive magnitude affects on rehearsal and free recall in subjects differing in chronological age. It was found that college subjects overtly rehearsed and recalled more words associated with a high rather than low incentive, and eighth graders showed a trend toward such results. In contrast, fifth graders failed to produce incentive level effects in either overt rehearsal or free recall. A follow-up experiment showed incentive level effects on recall for all three age groups in the more traditional free recall paradigm in which covert rehearsal was possible. Since the Cuvo study incorporated a within-subjects incentive level treatment, it was uncertain to what extent the obtained developmental differences in rehearsal could be generalized to the more conventional free recall paradigm in which

incentive level is not experimentally manipulated. In order to examine possible developmental differences in rehearsal and recall without the confounding effect of incentive motivation, the present research design is similar to that employed by Cuvo (in press), except that differential incentive was not experimentally induced.

It was anticipated that repetition of items immediately after their presentation would not account for the superior recall of college subjects. Adults, less dependent upon immediate repetition, would tend to re-enter stimuli into subsequent rehearsal sets for additional rehearsal, thereby prolonging the items' stay in short-term store and increasing the probability of coding operations (Cuvo, in press). Developmental differences were also hypothesized for the number of different words included in subjects' rehearsal sets, the rehearsal buffer size (Atkinson & Shiffrin, 1968), which should increase as a function of age (McBane, 1972). In addition to assessing developmental differences in rehearsal strategies, it was considered of theoretical interest to examine recall performance when rehearsal opportunities were minimized. Minimizing rehearsal should reduce transfer of early and middle list items to long-term store; thereby, attenuating the primacy portion of the serial position curve for children and adults (Cuvo, in press; Hagen & Kail, 1973). In the Overt Rehearsal condition, however, older subjects should show more prominent primacy effects because of more effective rehearsal strategies which enhance long-term storage (Cuvo, in press).

Method

Subjects

A sample of 60 subjects--20 fifth graders, 20 eighth graders, and 20 college adults--participated in the present experiment. Fifth and eighth grade children were selected from a pool of volunteers at Hall Memorial School in Willington, Connecticut, and college students, from

the University of Connecticut. The subjects were randomly chosen within grades with half from each sex. School children were white, from a rural community, and of average intelligence. College students were predominately white freshmen and sophomores participating as a requirement for the introductory Psychology course. All subjects were tested individually by the same experimenter in rooms provided by the schools.

Design

The experimental design included the following variables: Rehearsal (overt, minimal); Sex (male, female); Grade (5,8, college); and Lists (six). Rehearsal, Sex, and Grade were between-subjects variables, and Lists was a within-subjects treatment. Five males and five females from each grade were randomly assigned to the two independent rehearsal conditions, Overt Rehearsal and Minimal Rehearsal, and presented six different lists of unrelated words for free recall.

Material and Apparatus

Verbal stimuli to be learned in each of the two Rehearsal conditions were 120 singular nouns occurring 10-40 times per million words in English print (Thorndike & Lorge, 1944). For each of the six lists, 20 different words were presented with lists controlled to the extent possible for typical verbal learning variables. Twenty different three digit numbers were randomly selected for each of the six lists of the Minimal Rehearsal condition; the 120 digits were used for the counting backwards interference task that intervened between successive verbal stimuli. Words and digits were presented on slides by a Kodak Carousel projector. A sony casette tape recorder was used to record the overt rehearsal of subjects in the Overt Rehearsal condition, and the counting backwards for participants in the Minimal Rehearsal treatment.

Procedure

The initial step in each of the two Rehearsal conditions was to demonstrate the experimental task to subjects. For the Overt Rehearsal treatment, five practice words were shown for one second each; the screen was blank for four seconds between words during which overt rehearsal of any of the previously presented words was allowed. The experimenter overtly rehearsed the practice words in a spontaneous unsystematic fashion during the rehearsal intervals as a demonstration of the overt rehearsal procedure. Subsequently, subjects were presented the same five words for overt rehearsal and written recall. All rehearsal was required to be aloud; subjects were instructed not to rehearse covertly.

For the Minimal Rehearsal condition, a different three digit number alternated with each of the five practice words for demonstrating the counting interference procedure that intervened between successive stimulus words. During the demonstration, the experimenter said the word aloud once when it appeared, then said the three digit number when it came on, and then counted backwards by two's from that number until the next word was presented. Each word was on the screen for one second, with four seconds between words for the interpolated counting task. Subjects were instructed not to rehearse, either overtly or covertly, in the Minimal Rehearsal condition. The subjects engaged in the Minimal Rehearsal procedure for the five practice items subsequent to the demonstration, and produced written recall of the words they remembered.

Following demonstration and practice, subjects were randomly presented each of the six different word lists for free recall in the experiment proper. The procedure for the two Rehearsal conditions was similar to the pre-experimental training, with subjects engaging in either overt rehearsal or

the counting interference task for Overt Rehearsal and Minimal Rehearsal treatments, respectively. In the Overt Rehearsal condition, all rehearsal was required to be aloud, with words rehearsed and rate of rehearsal determined by subjects. In the Minimal Rehearsal condition, subjects were instructed to count backwards by two's as rapidly as possible. Overt rehearsal or counting backwards for the six lists was tape recorded for each subject. Two minutes were allowed for written recall following presentation of each of the six word lists in both conditions. Subsequent to each recall, 45 seconds were allocated for checking the accuracy of the recalled words in each condition and providing subjects with immediate feedback concerning their performance. It was not necessary for subjects to spell the words correctly in written recall. The experimenter asked subjects to identify misspelled items.

Results

Recall

Word recall means and standard deviations for the three Grade and two Rehearsal conditions are shown in Table 1. Inspection of the means reveals

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Insert Table 1 about here

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that word recall tended to increase as a function of age and was superior for Overt Rehearsal participants. A Rehearsal (2) x Sex (2) x Grade (3) x Lists (6) mixed models analysis of variance was computed for the recall obtained subsequent to each of the six list presentations. Collapsing across all other treatments, developmental differences were suggested by the increase in mean word recall per list across grades: $\bar{X}_{fifth} = 4.77$; $\bar{X}_{eighth} = 6.18$; $\bar{X}_{college} = 8.19$. The analysis of variance indicated a significant Grade main effect [F (2, 48) = 34.54, $p < .001$] and a subsequent Tukey test,

alpha set at .05, showed that these three age means differed from each other. The expectation that reduced rehearsal opportunities would attenuate list recall in the Minimal Rehearsal condition ($\bar{X}$ = 4.94), compared to unimpeded rehearsal in the Overt Rehearsal condition ($\bar{X}$ = 7.82), was confirmed [F (1, 48) = 72.15; $p < .001$]. The analysis of variance indicated no significant sex differences, changes in recall across lists, or interactions of the experimental treatments. However, a Grade x Rehearsal interaction [F (2, 48) = 3.04, $p < .10$] just failed to attain statistical significance. Inspection of Table 1 shows a trend toward a greater mean difference between Overt Rehearsal and Minimal Rehearsal recall for college adults compared to the two child groups.

It was anticipated that words which received more frequent overt rehearsal would also tend to be recalled more frequently. Figure 1 shows probability of recall conditional upon normalized number of rehearsals.

Insert Figure 1 about here

The latter measure was obtained by dividing the number of times an item was rehearsed by the total number of rehearsals for the 20 word list. This proportion avoids the possible confounding by the different rehearsal rates of subjects (Rundus and Atkinson, 1970). Data from the fifth through eighteenth serial positions inclusive were employed in this analysis. Early and late list items were not included in order to avoid confounding by serial position effects. Sex, grade, and List treatment data were collapsed. Figure 1 shows a strong positive correlation between probability of recall for an item and the mean normalized number of rehearsals of the item. The shape of the curve suggests that the amount of rehearsal accorded an item is a good indication

of its memory strength.

Analysis of Rehearsal Strategies

The basic purpose of this experiment was to analyze possible age related differences in rehearsal strategies which may have mediated the Grade main effect in recall. The Overt Rehearsal procedure, it will be remembered, required subjects to say the stimulus word as soon as it was presented, then to rehearse aloud any of the words that had been shown until the next item appeared. The words rehearsed subsequent to presentation of item m, and prior to exposure of item m + 1, defines a rehearsal set. In each rehearsal set subjects could have: (a) overtly repeated the most recently presented word, and/or (b) re-entered previously shown words for additional overt rehearsal. With these options possible, the overt rehearsal data contributed by the three age groups in the Overt Rehearsal condition were analyzed for four different strategies: number of repetitions per item across all subsequent rehearsal sets; number of different items rehearsed per rehearsal set; number of different rehearsal sets in which an item appeared; and, number of repetitions of an item in the rehearsal set immediately subsequent to its presentation (Rundus, 1970). Each of the four measures was subjected to an analysis of variance with Grade and Sex between-subjects variables and Lists a within-subjects treatment.

It was anticipated that sheer repetition, a rather rudimentary rehearsal strategy, would not account for the increased recall by adults. Thus, repetition, as a strategy, should not increase as a function of age. This hypothesis was tested by examining two different repetition measures: (a) number of repetitions accorded an item in the rehearsal set immediately after its presentation, and (b) number of repetitions accorded an item in all rehearsal sets subsequent to its exposure.

The first measure, number of repetitions granted an item in the 5 sec. rehearsal interval immediately subsequent to stimulus exposure, did not increase from childhood to adulthood: $\bar{X}_{fifth} = 3.14$; $\bar{X}_{eighth} = 3.70$; $\bar{X}_{college} = 3.24$. The analysis of variance indicated no significant main effects (Grade, Sex, Lists) or interactions.

The second rehearsal strategy, number of repetitions granted an item throughout all subsequent rehearsal sets, was also examined for possible age effects. The scores of this second rehearsal strategy are contrasted with immediate recall scores for the three age groups in Figure 2. Figure 2 shows nonsignificant changes in repetition means across grade levels

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Insert Figure 2 about here

[F (1, 24) < 1], but highly significant increases in recall. College subjects recalled significantly more words than children, but did not repeat them more frequently during rehearsal. Thus, the two nonsignificant repetition analyses suggest that the observed developmental increase in word recall was not mediated by an increase in item repetition.

In contrast, developmental changes were anticipated for the size of subjects' rehearsal buffer, the number of different items rehearsed at a given time. The first two rehearsal sets were excluded from the buffer size analysis because of the limited number of stimuli available for entry. The means showed an increase in buffer size as a function of age: $\bar{X}_{fifth} = 3.34$; $\bar{X}_{eighth} = 4.06$; $\bar{X}_{college} = 4.45$. The analysis of variance indicated a significant Grade main effect [F (2, 24) = 5.75, $p < .01$] and a subsequent Tukey test revealed that the fifth-grade and college samples differed from each other.

Another rehearsal measure, number of different rehearsal sets in which a stimulus word appeared, was expected to show age related differences. The mean number of items re-entered into subsequent rehearsal sets was 3.15, 3.81, and 4.16 for the fifth grade, eighth grade, and college samples respectively. The Grade main effect was significant [F (2, 24) = 5.78, $p < .01$], with the youngest and oldest age groups differing statistically. These latter two rehearsal measures indicate that the increase in recall as a function of age was mediated, in part, by developmental increments in: (a) rehearsal buffer size, and (b) number of different rehearsal sets in which a stimulus word appeared.

Short-Term Store, Rehearsal Buffer, and Long-Term Store Recall

Since age related differences in recall were found, the serial position curves for the three age levels were examined independently. If the recency portion of the serial position curve is a product of short-term store read out of terminal list items, and the primacy effect a result of long-term store retrieval of early and middle list items, then such curves should reveal possible developmental differences for these two memory stores. Figure 3 shows probability of recall for each of the 20 list positions for

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Insert Figure 3 about here

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the Overt Rehearsal participants. The curves, based on data from the six word lists combined, show increasing recall from the early and middle portions of the list a s a function of age. The recency part of the curve depicts negligible differences between the two younger age groups, but somewhat superior output for adults. These curves suggest that developmental differences obtained for both short and long-term store recall, with performance on the latter reflecting greater age differences.

It was expected that recall for early and middle portions of the serial position curves for Minimal Rehearsal subjects would be lower than for their Overt Rehearsal counterparts. Figure 4 shows serial position curves for the

Insert Figure 4 about here

three grades tested in the Minimal Rehearsal condition. A comparison of Figures 3 and 4 suggests that attenuating rehearsal opportunities in the Minimal Rehearsal condition served to markedly reduce the primacy but not the recency effect for all three age groups. The recency effect for all age levels is somewhat higher in the Minimal Rehearsal condition relative to that for their Overt Rehearsal peers.

The Overt Rehearsal condition rehearsal and recall scores for subjects at the three age levels were analyzed further in order to determine the relative contributions of short-term store, the rehearsal buffer, and long-term store to list recall. Items actively rehearsed in subjects' twentieth or final rehearsal sets on each list would have been in the buffer immediately prior to recall; they could have been represented in long-term store, as well. In contrast, items recalled from the early portions of the lists but not present in the final rehearsal sets would have been retrieved from long-term store. It has been shown that words in the final sets are likely to appear early in recall (Rundus, 1970) and the data were examined for this possibility.

The proportion of times which the first item recalled appeared in subjects' final rehearsal sets was computed from the Overt Rehearsal condition data for the three grades. The proportions for fifth grade, eighth grade and college subjects were .70, .68, and .83 respectively. These proportions indicate that the first item recalled was generally emitted

from the rehearsal buffer rather than long-term store irrespective of subjects age; the first item emitted by adults had the highest probability of residing in the short-term store rehearsal buffer. The relation of buffer to recall was analyzed further by calculating the proportion of total recall contributed by items in the final rehearsal set. The proportions of recall contributed by the buffer were .37, .50, and .40, for fifth-grade, eighth-grade, and college subjects, respectively; thus, somewhat less than half of total recall derived from the working component of short-term store. The additional items recalled could have been emitted from long-term store, short-term store, or a covert rehearsal buffer, contrary to instructions not to rehearse surreptitiously.

Another indicator of buffer contribution to recall is the proportion of items in the final rehearsal set which were emitted in free recall. High proportions were produced by each age level: .70 for fifth-grade; .83 for eighth-grade; and, .90 for college. Although these proportions increase with age, they indicate that almost all the buffer content was read-out as recall.

Discussion

The finding that free recall increased as a function of age replicates a number of past experimental findings (e.g., Cole, et al., 1971). However, previous recall studies have not examined directly the nature of subjects' rehearsal strategies which may have mediated age effects in recall. The overt rehearsal method of the present experiment, in contrast, permitted direct observation and measurement of specific rehearsal strategies. The principal findings of this study were that: (a) re-entry of previously presented items into subsequent rehearsal sets and an expanded rehearsal buffer may have accounted, in part, for the increased recall by adult

subjects, and (b) repetition of stimuli during rehearsal did not explain the positive correlation between age and recall.

Adult subjects tended to re-enter words into succeeding rehearsal sets for additional study. Such a strategy not only would maintain items in short-term store for a longer duration, but also provide the opportunity for inter-item association to take place. Re-entry may facilitate organization by allowing stimuli to come into close contiguity with other list members, and associated non-list items re-entered into buffer from long-term store. In addition, re-entry of items may have enhanced recall by serving as additional spaced presentation trials.

Correlated with re-entering items into subsequent rehearsal sets was the number of different words rehearsed at a given time, buffer size, which also showed an increase between 10 year old children and adults. The larger the rehearsal buffer the greater the number of stimuli in close contiguity and subject to organizational influence. Buffer size is affected by experimental conditions (e.g., the nature of stimulus items, their presentation rate, the degree of training) and subject strategies (e.g., rehearsal, coding). Although there is a limit to buffer size, it is not regarded as a fixed capacity, since it can vary as a function of experimental manipulations or subject strategies. However, buffer size may have an upper limit or fixed capacity, attainable with extensive training, and related to developmental level (McBane, 1972).

An interesting finding was the failure of item repetition to increase from childhood to adulthood, as both immediate and long-term store recall increased developmentally. Superior recall by college subjects could not be accounted for by frequency of rehearsal which, in effect, may have served as additional presentation trials. Repetitions within the same rehearsal

set may have functioned as massed presentation trials which are not as effective as spaced trials for enhancing recall (Bjork, 1970).

Other rehearsal considerations have been suggested by Craik (1973; Craik & Lockhart,1972) who proposed that stimuli proceed through a hierarchy of stages undergoing processing at various depths. Two principal types of processing were distinguished. Type I or maintenance rehearsal, includes item repetition which prolongs a trace's stay in the rehearsal buffer. Such processing maintains a stimulus at one level and does not enhance memory for the item. If stimuli are not attended to during Type I processing, their traces will decay and not be available for retrieval. Type II processing or elaborative rehearsal, on the other hand, involves a deeper analysis of the stimulus, including cognitive or semantic elaboration and enrichment. The deeper, elaborative rehearsal, in contrast to maintenance rehearsal, does lead to improved memory.

With respect to the present experiment, the item repetition measure reflects Type I processing only, and the results showed no significant differences in repetition with age. The two rehearsal measures which did show developmental differences, buffer size and re-entry of items into subsequent rehearsal sets, may have facilitated elaborative rehearsal by bringing into close contiguity more list items . Since the present experimental procedure involved single presentations of unrelated words, Type II rehearsal was not easily observed and measured. The information gleaned from the post-experimental interview of participants was difficult to quantify; however, subject reports were suggestive of age related differences in the use of organizational or coding processes to facilitate memory. Adult subjects may have engaged in deeper or more elaborative processing than younger children, thereby increasing their storage and retrieval of list items.

Developmental differences were also suggested in the operation of several memory stores postulated by the Atkinson and Shiffrin (1968) model. The serial position curves for the three ages tested in the Overt Rehearsal condition showed that adults had a higher probability of recall than children for items presented at nearly all list positions. Eighth graders tended to recall more words than fifth graders from the early portion of the list only. The correlation between age and the primacy effect probably suggests the use of more effective rehearsal strategies by older subjects, which permits greater transfer of items from short to long-term store. Buffer size, number of different rehearsal sets in which an item entered (which may have served as spaced trials), and elaborative rehearsal, may be some processes accounting for transfer of information to long-term store. The recency portion of the curve, reflective of short-term store and buffer content, showed negligible differences between the two child groups; adult performance, in contrast, was elevated relative to that of children. The fact that adults had a higher recency effect than children may suggest that the former are better able to empty their short-term store and buffer contents during the recall period. For example, there was a trend toward higher proportions of buffer content to be represented in recall. This finding of age related differences in recency (adults vs. children) is contrary to earlier results suggesting no age difference with respect to short-term store performance (Cole, et al., 1971). The serial position curves for Minimal Rehearsal participants showed that reducing rehearsal opportunities impaired recall and, presumably, long-term store transfer of early and middle list items, irrespective of developmental level. The higher recency effects at each grade level for Minimal Rehearsal subjects, compared to Overt Rehearsal participants, may have obtained because there were fewer list

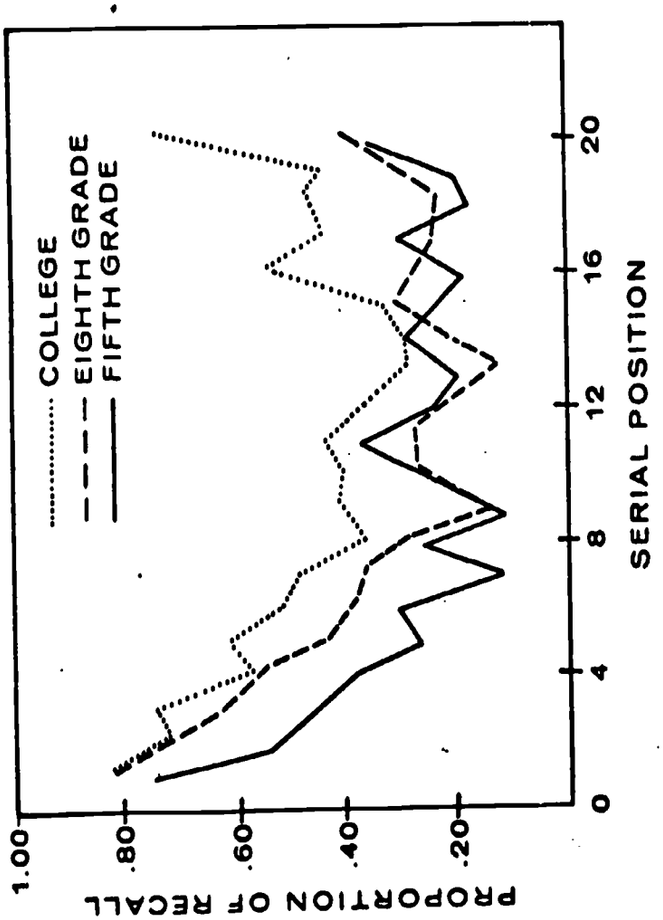
items in short-term store competing for output.

Developmental increments in free recall, thus; seem to have been mediated, in part, by increases in: (a) buffer size, (b) number of rehearsal sets in which an item was entered (spaced trials), and (c) elaborative rehearsal. Frequency of stimulus repetition did not seem to account for superior adult recall.

TABLE 1

Mean Word Recall Per List for Grade and Rehearsal Conditions

	Grade					
	Fifth		Eighth		College	
	M	SD	M	SD	M	SD
Overt Rehearsal	5.93	1.37	7.30	1.57	10.22	2.56
Minimal Rehearsal	3.60	1.74	5.07	2.35	6.17	1.84


COLLEGE
EIGHTH GRADE
FIFTH GRADE
PROPORTION OF RECALL
1.00
.80
.60
.40
.20
0
4
8
12
16
20
SERIAL POSITION

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Footnotes

1. These data were collected while the author was a doctoral candidate at the University of Connecticut. The author is indebted to Marlene Cuvo for assistance in data analysis and Gordon White for computer consultation.

2. Requests for reprints may be sent to the author: Rehabilitation Institute, Southern Illinois University, Carbondale, Illinois 62901.

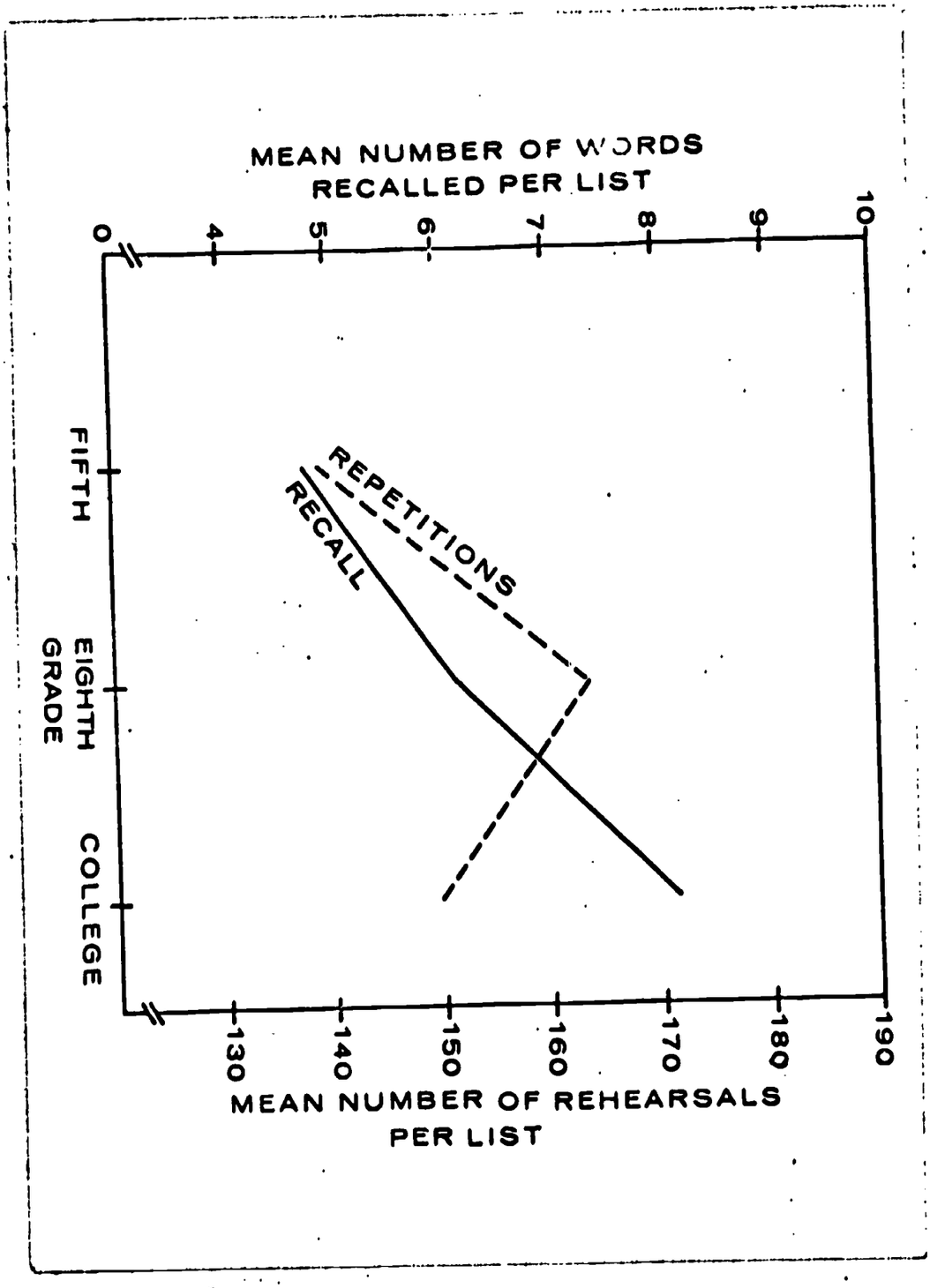
FIGURE CAPTIONS

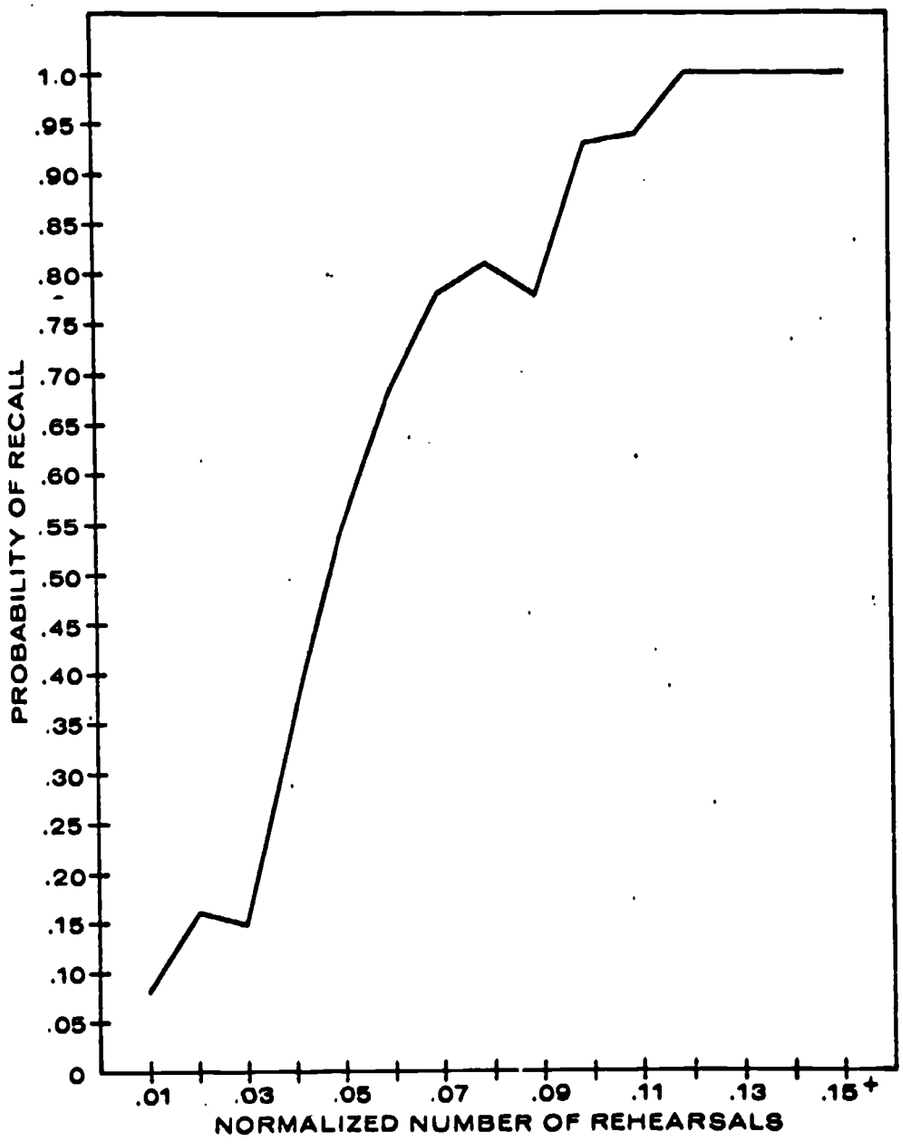
Fig. 1. Probability of recall conditional upon normalized number of rehearsals.

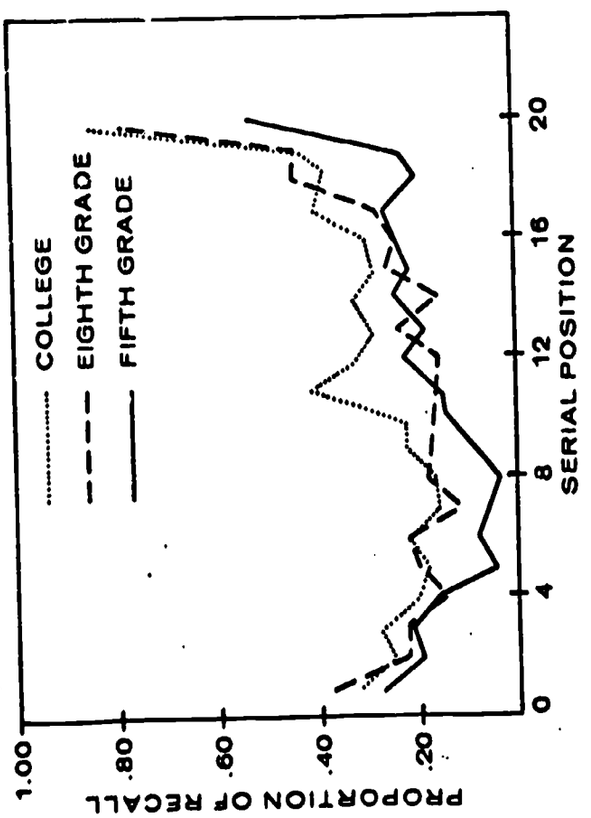
Fig. 2. Repetition and immediate recall as a function of age.

Fig. 3. Free recall serial position curves for fifth-grade, eighth-grade, and college subjects in the Overt Rehearsal condition.

Fig. 4. Free recall serial position curves for fifth-grade, eighth-grade, and college subjects in the Minimal Rehearsal condition.


MEAN NUMBER OF WORDS
RECALLED PER LIST
0
4
5
6
7
8
9
10
FIFTH
EIGHTH
GRADE
COLLEGE
REPETITIONS
RECALL
130
140
150
160
170
180
190
MEAN NUMBER OF REHEARSALS
PER LIST


PROBABILITY OF RECALL
1.0
.95
.90
.85
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0
.01
.03
.05
.07
.09
.11
.13
.15+
NORMALIZED NUMBER OF REHEARSALS


COLLEGE
EIGHTH GRADE
FIFTH GRADE
PROPORTION OF RECALL
1.00
.80
.60
.40
.20
0
4
8
12
16
20
SERIAL POSITION